Fall 2020

# Test Anxiety and Mathematics Teaching Strategies in Youth Mathematics

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A Mathematical Aversion

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An Aversion Towards Mathematics

**Introduction**

Being a K-12 student in the 21st century presents students with significantly different demands than previously known. Students and teachers alike frequently express their dislike of standardized testing, stating opinions of uselessness, wasting of time, etc. Teachers are scrutinized based on the performance of their students on these high-stakes examinations; therefore they push their students to retain as much information as possible in order to adequately perform on these assessments. Teachers often verbalize the strain they are under when preparing their students for these end of course examinations, but what about the students? Students are tasked with the daily struggle of switching to different subject areas, adjusting to different instructional styles, and are required to balance multiple academic and extracurricular activities. When these activities are conjoined with high stakes tests, students can become disengaged. This literature review will be broken down into two components. First, the psychology of an aversion (specifically a math aversion), and how standardized testing has helped to fuel this trend for aversions. Second, how can teachers/administrators modify the educational system to allow students the opportunity to creatively express themselves without being tied down by the constraints of standardized testing?

**Math Aversion**

It is not uncommon to hear students acknowledge that they are not fond of mathematics, but why is this seemingly occurring only in the field of mathematics? According to Susan S. Stodolsky from the University of Chicago, this is due to the type of instruction. She writes, “In contrast to other school subjects, math instruction provides students with only one route to learning: teacher explanation followed by student practice…” (Stodolsky, 1985). While other school subjects frequently partake in interactive debates, discussions, and hands-on labs, students in a mathematics classroom are held at their desks repeating the same process stated above each academic learning day. Mathematics is also a subject where there is only one correct answer. The correct answer in other content areas are ambiguous at times, therefore they can be discussed and elaborated on (Stodolsky, 1985). These same interactions hold true for areas of higher learning as well. In college level mathematics courses, for example, students are expected to visit a professor in their office to receive academic aide with homework, test preparation, etc. It is shown that the teacher is at a higher knowledge level than the student, and is therefore able to obtain this material from an expert (a professor) instead of synthesizing their own conclusions independently. When this is compared to a psychology professor, Stodolsky states that the expert in the field (a professor) has interactive discussions with students, where they are able to debate the meaning of texts, rather than a professor telling a student what is right.

This level of interaction provides a student with a sense of worth, where they are interacting with their learning environment instead of being a passive recipient of their education (Stodolsky, 1985). This is evident at the college level, but when are these ideas formulated? Research has shown that younger children through their elementary years have positive attitudes towards mathematics (Goodlad, 1984). In a study involving over 17,000 students tested on their affinity for academic subjects, math ranked equal to reading (Goodlad 1984). In similar studies, 9-year-olds ranked mathematics as their favorite subject, 13-year-olds ranked it as their second favorite, but 17-year-olds placed it as their least favorite subject (Carpenter et al., 1981). There are very few numerical metrics that measure affinity for an academic subject or anxiety; rather, they can be assessed through self-reported metrics, such as questions that ask participants to answer questions on a numerical scale.  While researchers are able to determine underlying causes of math anxiety, there has been sparse research on demographic rates for math anxiety (Stodolsky, 1985).   In the classrooms in the aforementioned study, the instructional techniques, expected behavior, and materials needed were very similar. In contrast, the environment in all studied social studies classrooms was drastically different.  Instead of seatwork and reciting the teachers lecture, social studies students had the opportunity to present, debate, and defend themselves (Stodolsky, 1985). Adolescent students have creative minds, which are infrequently satisfied through lecture-based learning in conjunction with seatwork.  While this style of instruction is necessary, it can be better served as a supplementation to other forms of instruction.  By allowing students the opportunity to investigate for themselves and partake in problem-based learning activities, students will be able to engage in social interaction about mathematics.  This style of learning can then use a summary lecture or individual instruction to fill in any knowledge gaps.

**Math Testing Anxiety**

Of the many ways in an educational system in which teachers can gain an understanding for the amount of information students have retained, the most popular of which being through assessments.  Every student has experienced a fear of failure on assessments.  Is that fear normal, or is it a result of a flawed academic system that stresses scores more than the learning process?  Similarly, are students motivated to learn, or simply to earn enough points throughout a grading period to please their parents?  According to an article by Clarke, Abrams, and Madaus, rewards such as grades and threats of sanctions, such as denial of a high school diploma will boost students' motivation. This indicates that a majority of students are motivated not by the willingness to learn new information, but by external motivators such as grades and threats of denial (Clarke, Abrams, and Madaus, 2001). Through this information, it can be inferred that students stress less the daily academic learning process only to push information upon themselves for a major assessment. Research by Pintrich and Schunk has shown that these motivational beliefs and cognitive processes not only differ from the goal of well-trained educators, but also show that students believe these beliefs are important to achievement in the classroom (Pintrich and Schunk, 2002). One major motivation factor is achievement goals.

Achievement goal Theory allows goals to be conceptualized through organized lists of tasks regarding beliefs about purpose of goals (assessments), competence, and success that influence the approach, engagement, and the way in which the goal is evaluated within its specific context (Ames, 1992; Dweck and Leggett, 1988). A study conducted by Katherine Ryan and colleagues analyzed students through different sets of goals. They were able to identify multiple different goal orientation strategies, the first of which was deemed "mastery-approach goals." A student who possesses mastery-approach goal mindset focuses on mastering a task. These thinkers often approach challenging tasks, attempting to reference others previous achievements to achieve further success (Ryan, et al). Famous mathematicians who solved complex problems most likely approached their work through mastery-approach goals. Conversely, master-avoid goals are characterized as a focus on avoiding errors and preventing a negative outcome when performing a task (Ryan, et al). These students are likely to pursue a task in which the likelihood of failure is minimal, in order to prevent a negative outcome (Ryan, et al). Instead of focusing on mastery goals, researchers identified goals related to performance. A performance-approach goal focuses on demonstrating above average ability in an effort to look smart when compared to peers of similar ability (Ryan, et al). Students who fall into these categories show their peers, parents, or mentors their examinations or papers to show their above average intelligence. In contrast, those who exhibit performance-avoid goals are concerned with avoiding negative judgement based on their work, or “avoiding looking dumb” (Ryan, et al).

Similar to goals, value is also a large proponent that is used to motivate students (Eccles, 1983, 1993). Educators typically assign fewer point values to homework, in-class activities, and other assignments while assigning higher point values to tests and examinations. In doing this, teachers are reducing the value of the learning process, and placing a higher value on assessments that have been shown to cause additional stress on students. Historically, researchers have consistently found a correlation between high test anxiety and lower achievement (Crocker et all., 1988; Hembree, 1988; Smith et al., 1990). With respect to mathematics assessments in particular, research has found that cognitive processes can be altered by anxiety through testing (Entwhistle, 1988). Specifically, cognitive disorganization has been commonly found to be altered by anxiety, which is characterized by distracting thought that can lengthen time used when solving problems, as required on mathematical assessments (Entwhistle, 1988).

**Causes of Math Aversion**

Students openly discuss their avoidance of mathematics, and identify particular reasons for their aversions. A study conducted by Unal Ufuktepe and Clair Thomas Ozel found that children encounter mathematics already having fears of mathematics brought on from the society around them (Ufuktepe et al., 2003). This preconceived notion results in students exhibiting a lack of confidence and avoiding of creative mathematical thought processes as a result of external circumstances that arise before the students can even be exposed to their own thoughts and ideas. The media is also changing the way in which mathematics is conveyed. In our society, mathematics is often conveyed as difficult, abstract, and requiring intellectual curiosity (Ufuktepe et al., 2003). The public is not properly informed about the field of mathematics and the secrets which it hides. Many are under the speculation that mathematics is only to be practiced by those who are mathematically gifted, leaving those who aren't considered mathematically gifted unable to practice mathematics (Ufuktepe et al., 2003). In addition to the media creating perceptions about math aversions, teachers can also feed into the thought that certain students are made more mathematics while others cannot excel in the field. Many subjects such as literature and history have discussions and debates which can be incorporated into the curriculum (Ufuktepe et al., 2003). In contrast, teachers of mathematics place an emphasis in memorizing formulas and often teach using drills, practice, and memory rules (Ufuktepe et al., 2003). This teaching method is contrary to how mathematics should be approached, as an inquiry-based art that allows students the opportunity to utilize crucial reasoning, problem-solving, and understanding skills (Greenwood 1984). Instead of being able to argue and debate their arguments as in other academic disciplines, the field of mathematics is historically taught as a right versus wrong discipline.

Students fear failure, and therefore cannot perform their best work when afraid (Ufuktepe et al., 2003). A study performed by McLead found that the critical age for the development of mathematics trauma is between 9 and 11 (McLead, 1993). This study utilized cooperative learning, which breaks a classroom into smaller groups. Each group approached mathematics in a different way, some utilizing the mathematics in music, while others performing investigation-based activities (Ufuktepe et al., 2003). The study helped to shed light on the fact that teaching styles did not match the learning styles of the students. Utilization of a broader approach towards teaching mathematics which allows students to use investigative skills rather than simply follow a list of steps (Ufuktepe et al., 2003).

**Is Math for Everyone?**

As children enter formal schooling, they become exposed to many different stimuli, all of which can influence their academic choices. Many research articles have shown that as children enter formal schooling, their constructive process can decrease, especially in young girls and those from minorities (Ma, 2003; Scarpello, 2007; Turner et all., 2002). Instead of learning through self-exploration and by learning through performing activities, children in elementary education begin to become reliant on learning through textbooks (Geist, 2000). This shifts the focus of instruction for students from construction of concepts and thoughts to methods imposed by the instructor for obtaining the correct answer (Geist, 2000). Instead of fostering creativity and allowing students to construct their own mathematical thoughts, teachers focus on repetition efficiency, often in the form of timed tests. These tests gauge the ability for a student to accurately complete a number of addition, subtraction, division, or multiplication problems. These have been found to undermine a child's thought process and leads to negative attitudes towards mathematics (Popham, 2008; Scarpello, 2007; Thilmany, 2004; Tsui & Mazzocco, 2007). Those students who think through math questions at a slower pace perceive that they are inferior to their peers in mathematics, therefore feeding into a negative perception of mathematics. These timed tests emphasis repetition, which deviates from the reality of the field of mathematics.

As a result, children who had early success with mathematics find the repetition tedious and counterproductive to their goal of exploring the field of mathematics, causing them to disengage (Popham, 2008). This method of instruction prepares students to use memorization skills when solving problems, rather than building their own connections between material and using problem-solving skills (Geist, 2010). In addition, evidence shows that timed tests and other high stakes assessments affect girls' attitudes towards mathematics more than boys, which leads to girls being less likely to pursue higher level mathematics (Beilock, 2008). Also, these students, regardless of gender, may actually be retaining less information. The method of memorization is significantly lower on Bloom's Taxonomy than problem-solving. As a result, students become less engaged when simply memorizing material will allow them to excel in a mathematics course. Educating students by having them memorize in mathematics rather than problem solve also increases mathematics testing anxiety. This is due to the fact that students who memorize information either know the answer, or they do not. As a result, these students attempt to "cram" before an assessment, while remembering bits and pieces of useless information. On the contrary, those students who learn mathematics through problem-solving are able to reason through challenging problems, pulling information from different sources rather than memorizing bits and pieces of information (Geist, 2010). The field of mathematics has been manipulated by the teaching strategies of educators. Mathematics has slowly become transformed from a creative, investigative art to an efficient, orderly process (Geist, 2010). This orderly process is an inaccurate representation of the true beauty of mathematics, and allows further explanation into the insight of a generation growing up without a fondness to continue their studies of mathematics. As highlighted in the aforementioned paragraph, mathematics is for all learners, as all learners deserve the opportunity to delve into the depths of mathematics and investigate its hidden beauties. Many would be opposed to continuing the study of a field in which they were told what to do and when to do it. As a result, there are certain ways in which educators can adapt to better prepare the next generation of students for successful mathematical careers, those which are filled with investigation and avenues for students to fuel their curiosities.

**Does Background Affect Mathematical Attitude?**

Many have found that performing tedious work can only be done in certain places. Maybe at a silent office, or at a local coffee shop free of distraction. Can classroom environment positively or negatively affect a student's ability to enjoy mathematics? According to a study conducted by Midgley and colleagues, there is evidence that positive motivation is necessary for students to hold constructive educational beliefs and behaviors (Midgley, Kaplan, and Middleton, 2001). Additional studies took this finding one step further, and analyzed whether motivation alone is enough for increased educational behaviors or if a demanding classroom environment is also necessary (Middleton and Midgley 2001). As discussed earlier, when learners are focused on not making a mistake or seeming unable, they adopt performance-avoid goals, where the focus is on avoiding self-failure rather than challenging the mind to master new topics (Middleton and Midgley 2001). Many studies have shown that the aforementioned goal orientations are associated with patterns of outcomes indicated in students who are lesser adapted for learning. This form of academic press can prove to have negative consequences on the academic learning environment for students. Evidence has shown that both motivational goals and educational history can change the outlook a student has on a perspective teacher. For example, two students could be seated in the same classroom, yet have two different impressions of the teacher in terms of the level of demand asked of them and the purpose behind the work that is being performed (Middleton and Midgley 2001). Educators must continue to realize that students are unique and come from everchanging and diverse backgrounds. The intended outcome of a lesson may deviate from the perceived outcome from student to student (Middleton and Midgley 2001). Perceived outcome of a lesson can change from student to student depending on their background, but can it also change by gender?

Research suggests that boys often ask "more difficult" questions than girls within a mathematics classroom (Kahle & Meece, 1994). Additional research also suggests that boys may therefore experience a greater press for understanding than females, linking more explorative tendencies (Oakes, 1985). The study conducted by Middleton and Midgley sampled 512 students from 5th through 9th grade in what was described as "working and middle class" school districts. This study analyzed the relation between the learning environment and students' academic and emotional well-being as they progressed throughout middle school and into high school. The study found that a task goal orientation separate from the previously discussed academic press for understanding (Middleton and Midgley 2001). That is, students may be independently doing their work to improve, and this is related but distinctly different than a teacher urging students to perform their own work (Middleton and Midgley 2001). The results of this study also suggested that when a student has a task goal orientation, it promotes positive academic beliefs and behaviors that aide in student learning. Likewise, this press provides further benefit than holding task goals (Middleton and Midgley 2001). As far as teachers are concerned, they are concerned about student apathy according to a study by Twomey and Morin, and are able to identify students who perform the minimum work that is asked of them (Twomey & Morin, 1999). This study indicates that teachers should academically press students at differing levels, as students appear to benefit from how much they are perceived to be academically pressed by the teacher (Middleton and Midgley 2001). If teachers are able to connect with students and understand their background, they will have a better understanding of the perceived pressing an individual student needs to perform at their best without discouraging the student.

**Is Math Explorative?**

Mathematicians earn fame through proving previously unsolved theorems, and forming conjectures that change the realm of mathematics. These mathematicians tell stories of isolating themselves for multiple years in order to prove the theorems they proved. This took years of mathematical creativity and innovation, all of which is not emphasized when teaching mathematics to our current youth. In her book *Mathematical Mindsets*, Jo Boaler states "When we do not show the breadth of mathematics to students, we deny them the chance to experience the wonder of mathematics," (Joaler, 2016, p. 26). Boaler is presenting an argument that has dominated the teaching of 21st century mathematics. Mathematics isn't explorative for students. Math classrooms are predicated on a teacher lecturing, students copying notes and memorizing patterns that are repeated for each problem in the lesson before moving on to a new topic. This gap in mathematics education was noticed by mathematician Rueben Hersh, who wrote in his book *What is Mathematics, Really?.* He states, "Solving problems and making up new ones is the essence of mathematical life. If mathematics is conceived apart from mathematical life, of course it seems-dead," (Hersh, 1999). This was later supported by many in the mathematics community, and laid the framework for the push to rework the teaching of mathematics. In the beginning of the 21st century, students would learn mathematics by spending thousands of hours learning different sets of procedures, memorizing formulas with little to no understanding of their origins, all to never use them in their lives or in their respective job fields (Boaler, 2016, p. 27). Conrad Wolfram is the director Wolfram-Alpha, a very well-known mathematical company worldwide. During a TED talked in 2010, Wolfram proposed a four stage model for working on mathematics. The first stage focused on posing a mathematical question. The next stage was taking that real world question and working it into a mathematical model. Once the problem was in a mathematical problem, the third stage was performing a calculation. Finally, the last step is to take the solved model back into the real world to see if the originally posed question was now solved (Wolfram, 2010). Wolfram furthers his discussion by pointing out that students spend upwards of 80% of their mathematical careers on stage 3, performing a calculation. When this model is used in a real-world setting, the third stage is the least crucial.

This is due to the 21st century technology available, which can perform most calculations more accurately and efficiently than a human (Wolfram, 2010). Instead, Wolfram proposed that mathematics education should be focused on stages one, two, and four as employers seek employees who are able to pose questions, analyze results, and apply those results rather than an employee who can perform work at half the efficiency of a computer (Wolfram, 2010). Forty-five years ago, Fortune 500 companies were asked what attributes they valued most in new employees. Computation skills ranked second on that list, behind writing. In 1999, those same companies were again asked the same question, only with significantly differing results. Computation skills fell to second-last on the list, with the top spots being taken by teamwork and problem-solving skills (Boaler, 2016, p. 28). The top skills forty-five years ago have been taking over by technology. Writing skills are obsolete in a work environment, as technology has allowed conference called, voice text features, and other forms of technology to mitigate its importance. Technology is drastically changing the needs of our workforce, and more emphasis is being placed on collaboration. Leone Burton studied the work of famous mathematicians, and the results she found proved to work in balance with the valued skills of companies. She found that over half of the publications of mathematicians were produced collaboratively (Burton, 1999). That is, these mathematicians worked better together than individually. Fortune 500 companies value teamwork, and famous mathematicians even value teamwork, yet the educational system teaches mathematics through worksheets that are to be completed in silence (Boaler, 2016, p. 29). Mathematics education is predicated on independent work that is to be performed as efficiently as possible, and this model represents a failure of the educational system to adapt to the everchanging demands of industry. Performing investigative work in group settings is what is needed to revolutionize the field of mathematics education.

**One Route to Learning**

As soon as students are of the age to begin finetuning their computational skills, they are met with countless memorization tactics. The introduction of timed tests also stresses the efficiency of the students' memorization skills (Boaler, 2016, p. 39). Students are presented with tables in which to perform certain operations and are given a basis for which memorization of these tables can become possible. This method of memorizing math facts is the first indicator a young student receives of their mathematical efficacy. This may seem flawed, but does memorizing math facts have an indication of the mathematical potential of a young student? Recent brain studies analyzed the brain of students as they were taught to memorize math facts. As expected, researchers observed that some students were able to memorize math facts quicker than other students. The staggering question remained, what indication did this have on the "math ability" of the students? The only significant difference researchers could find was in the hippocampus of the brain, which is responsible for the memorization of facts. There was no significance detected in IQ scores of any other measure indicating intelligence (Supekar et al., 2013). The essence of this study brings to light that the efficiency at which students learn math facts has no bearing on their mathematical potential. Also, the ability of the brain to memorize facts has no impact on the mathematical potential of students (Boaler, 2016, p. 40). As previously discussed, the study of mathematics is far from memorizing formulas, meaning that teaching young students to memorize times tables provides no indication of their mathematical potential (Boaler, 2016, p. 40). However, teachers and administrators use data from timed tests to place students in tracks within their grade, using this tests as an indicator of the mathematical potential of each student. Memorization and speed is rewarded by teachers, indicating to students that those skills are a precursor to high mathematical ability, whereas many sources have denied that either quality is important in the study of mathematics.

Not only are teachers and administrators buying into this method of mathematical instruction, textbooks also teach in similar ways. Most mathematics textbooks isolate a singular method for a particular section, reduce it to its simplest form, and utilize repetitive practice to allow students to understand that method (Boaler, 2016, p. 42). This is a problem for many reasons, mainly because it brings on a sense of boredom for students. They passively accept the model, and become ready to move onto newer models to avoid repetitive practice (Boaler & Greeno, 2000). Other problem is that these repetitive textbook problems provide students with the simplest version of the particular method, allowing students to gather minimal understanding for when this method can be used outside of the provided set of problems (Boaler & Greeno, 2000). The current textbook model teaches students that mathematics is taught in fragments. There is a model that is introduced, the student is to memorize the model, then apply the model to a set of pre-made questions, and repeat the process for each new model. In an observational study conducted in United States schools, students were asked what their role was in the math classroom. Of all students surveyed, 97% replied that their role was to "pay careful attention," (Boaler & Staples, 2005). Also supported by textbooks, students are being put under the impression that the best way to learn about mathematics is to passively watch, rather than think, engage, and ask questions (Boaler & Staples, 2005). Students are being taught that the time to actively engage in mathematics is independently at home, when doing homework. This is contrary to the findings of research, which state that mathematics is best understood through collaboration and discussion (Boaler, 2016, p. 29). The teaching of mathematics has been trending in the opposite direction of viable research, pushing mathematically minded students away from the field, while also increasing frustration and anxiety placed on learning new forms of mathematics.

**Evolution of Mathematics Education**

The technological advancements of the 21st century have changed the demands of the workforce, therefore changing the skills employees must possess. As a result, the educational system has been evolving with new forms of technology. How can mathematics education evolve to mimic the everchanging demands of the workforce? As previously discussed, the evolution of mathematics education has been slower than the advancements of our workforce, and schools are beginning to change. This change began at the turn of the century. Andee Rubin, mathematician and computer scientist, understands that mathematical literacy goes far beyond arithmetic computation. He writes, "…a comfort with geometric analyses of space, both two and three dimensional, an understanding of what different representations of mathematical quantities-such as graphs mean and how they relate," (Rubin, 1999). As a trained computer scientist, Rubin was among those at the forefront of introducing technology into the field of mathematics. Throughout the beginning of the 21st century, mathematics has continued to evolve through technology, and mathematician/author Jo Boaler evolved with it. Her development of the website YouCubed allows students to enter creative areas of mathematics through technology, while also developing growth mindset messages through forms of productive struggle (Boaler). Boaler's website allows students, teachers, and parents the opportunity to engage in interactive lessons while also understanding the meaning behind their work.

Other websites provide similar interactive abilities, while also allowing students the opportunity to use their creative thoughts for interactive purposes. Desmos allows students the opportunity to manipulate functions and receive immediate feedback about how changing a function changes the features of its graph. Also, teachers can use preconstructed lessons on Desmos as a method of producing interactive games for their students (Desmos). The use of technology in the workforce is drastically increasing, as is the demand for technology in educational environments. Through interactive online activities, students can become comfortable learning through online interaction, preparing them for the workforce.

**Conclusion**

The field of mathematics is everchanging and uniquely diverse compared to other subjects in academia. Although mathematics has been taught as a list of procedures and formulas, it in truth is a creative thought process that challenges the mind to form connections between conceptual thought processes. The way in which mathematics is taught and assessed in our school systems brings about evident flaws that show themselves in the form of test anxiety and aversions towards mathematics. As the logic behind mathematics education evolves, the intent is for the negative consequences of anxiety to significantly diminish. No model is perfect, although there is evidence indicating newer proposed models are significantly more effective at teaching mathematics and reducing anxiety in the student population. As with all of areas, learning and adaptation is required long before mastery can be attained. As famous author and pastor Charles R. Swindoll said, “Life is 10% what happens to me, and 90% how I react to it.” It’s time for educators to react and positively alter the course of mathematics instruction.

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